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ABSTRACT

Two studies examined the effects of on-line processing and memory-based processing on the transfer of analogy problem-solving strategies. Male and female college students (N=189) were randomly assigned to one of three experimental groups and a control group. Each experimental condition involved a different type of training strategy (advice, feedback, or advice and feedback) for solving analogies. The training trials were administered in order to establish problem solving schemata during practice. The control group received no training. Following the training trials, a common transfer task was administered to determine whether general and/or specific problem-solving schema were used as the basis for transfer. The first study included a transfer task administered immediately after training (on-line transfer), while the second study involved a 7-day interval between the training and transfer tasks (memory-based transfer). Results indicate that transfer was superior in the experimental groups of both studies. In addition, on-line processing and memory-based processing produced similar transfer effects. Consequently, the findings support the interpretation that the problem-solving schema established during training was utilized for the transfer task. Three tables and one figure are included. (Author/TJH)

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On-line and memory-based problem solving:

A comparison of transfer effects

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Running head: ON-LINE AND MEMORY-BASED TRANSFER

ABSTRACT

This study examined the effects of on-line processing and memory-based processing on the transfer of analogy problem-solving strategies. One hundred eighty-nine male and female college students were randomly assigned to one of three experimental groups or a control group. Each experimental condition involved a different type of training strategy (advice, feedback, advice & feedback) for solving analogies. The training trials were administered in order to establish problem solving schemata during practice. The control group received no training. Following the training trials, a common transfer task was administered to determine if general and/or specific problem solving schema were used as the basis for transfer. The first study included a transfer task administered immediately after training (on-line transfer), while the second study involved a seven day interval between the training and transfer tasks (memory-based transfer). Results indicated that transfer following training was superior to the transfer performance of the control group in both studies. In addition, on-line processing and memory-based processing produced similar transfer effects. Consequently, the interpretation that the problem solving schema established during training was utilized for the transfer task is supported by these findings.

On-line and memory-based problem-solving:

A comparison of transfer effects

A widespread concern among educators and researchers today involves the question of how an individual acquires the ability to apply previously demonstrated knowledge to a different problem in the same context or a different problem in a different context (Cormier & Hagman, 1987; Phye, 1989). Although it is assumed that the educational system is facilitating this process, many students experience difficulties in what is known as the transfer of knowledge. The purpose of this research was to investigate two types of problem-solving involved in transfer and how various training strategies influenced them. In addition, this study attempted to replicate previous findings that transfer occurs due to the utilization of a problem solving schema induced during training (Phye, 1989).

A transfer task may immediately follow the initial training of a problem solving strategy or it may follow an interval of days or weeks. For both educational and theoretical reasons, training that impacts delayed transfer as well as immediate transfer is of central interest in understanding transfer. Surprisingly, studies of delayed transfer are infrequently found in contemporary work (Gick & Holyoak, 1987). The need for a distinction between immediate and delayed transfer tasks is indirectly addressed by Hastie and Park (1986) in the social-cognition literature. Hastie and Park differentiate between judgments that are made within a processing episode (on-line) and judgments that follow the processing episode and are based on knowledge retrieved from long term memory. Salomon and Perkins (1989) have addressed this distinction within the context of transfer tasks by using the terms forward reaching (on-line or within a contiguous episode) transfer and backward reaching (memory-based) transfer. "Such transfer can either be of the forward-reaching kind, whereby one

mindfully abstracts basic elements in anticipation for later application, or of the backward-reaching kind, where one faces a new situation and deliberately searches for relevant knowledge already acquired" (Salomon & Perkins, 1989, p. 113).

The distinction between information processing that is on-line processing and the processing of information that is clearly memory-based has application within the context of teaching transfer. During acquisition, training requiring multiple practice trials would involve both encoding and memory retrieval. If informative feedback is included in the training phase as well, then judgment or decision making is also involved in on-line processing. At transfer, when the task is delayed and problems are new, successful solution would require memory retrieval for problem identification and strategy selection. Problem solving performance on a delayed transfer task would be predicated on memory-based processing that emphasizes the retrieval of appropriate schema.

Since most research utilizing the training for transfer paradigm employs a transfer phase that immediately follows training, it is difficult to evaluate the distinction between on-line and memory-based transfer. This research involved the investigation of both immediate and delayed transfer so as to provide the opportunity to test the validity of the on-line and memory-based distinction as it applies to transfer tasks of a problem-solving nature.

Another area of interest deals with transfer within or between subclasses of specific problems. Specifically, this study focused on the training of analogy problems involving cause-effect solutions. The transfer task, however, consisted of association and part-whole analogies, as well as those with cause-effect solutions. According to Sternberg's (1985) levels of generality principle, both types of analogies are subsets of the problem class of analogies. Figure 1

represents an incomplete hierarchical domain structure for inductive reasoning. The use of the two subsets of analogies in this study provided the opportunity to investigate schema transfer between subsets of the reasoning class of analogy problem-solving.

Insert Figure 1 about here

In the present study, then, the following research questions were addressed: (1) Does training have a positive impact on the transfer of verbal analogy problem solving? (2) Is there a significant difference between the effects of various training conditions (advice, feedback, advice & feedback) on training and transfer performance? (3) Is there a significant difference between the transfer performance of on-line processing and memory-based processing? (4) Does transfer occur across a subclass of analogy problems as well as within a subclass of analogy problems?

Based on previous results with on-line transfer, schema inducement during training via the use of advice, feedback, or a combination of the two will prove effective in promoting memory-based transfer. Based on results from on-line transfer and schema inducement, it is anticipated that training in the advice condition will produce results that provide insight into the generic issue of how training for transfer differs from training for rapid acquisition (Cormier & Hagman, 1987).

EXPERIMENT 1

METHOD

Subjects

Ninety-one male and female students at Iowa State University received extra credit in an undergraduate psychology course for participating as

subjects. All participants were treated in accordance with APA guidelines for human subjects.

Design

The basic paradigm used in the study is presented in Table 1. The experimental condition involved training for verbal analogies having cause-effect relationships. Each training condition consisted of three practice trials followed immediately by a transfer task. Within each training condition, three types of practice served as the basis for the inducement of a general or procedural schema during training. The three types of practice were: 1) general advice prior to the first practice trial; 2) corrective feedback following practice trials one and two; and 3) both advice prior to practice and corrective feedback.

Insert Table 1 about here

The same transfer task was administered to all subjects regardless of the type of training received. The no-treatment control group also performed the identical transfer task. The transfer task consisted of 20 verbal analogy problems different from the analogy problems used in training. Half of the analogies involved cause-effect (C-E) relationships, while the other half contained association and part-whole (A&P-w) relationships.

Procedure

Training was conducted in small groups. Participants were randomly assigned to groups. Subsequently, groups were randomly assigned to experimental or control conditions. During training and transfer, items were shown by a carousel projector at the rate of one item every 10 seconds with a .05 second interstimulus interval. At transfer, items were blocked (10 C-E and

10 A&P-w). Order of presentation was counterbalanced across groups. Subjects recorded their answers on a standard answer sheet, and answer sheets were collected after each practice trial.

RESULTS

Training Data

Training data were analyzed using a 3 (type of practice) X 3 (trials) split-plot analysis of variance with repeated measures. Training means are provided in Table 2. A significant Training Condition X Trials interaction was obtained, $F(4,136) = 22.34$, $p < .001$. Differences between means were tested using Tukey's Honestly Significant Difference (HSD) test of means, HSD = 2.01. Significant improvement was revealed across trials within the two practice conditions involving advice and feedback (A&F) and feedback only (F). The practice condition involving advice only (A), however, contained significant improvement between Trials 1 and 2, but not between Trials 2 and 3.

Insert Table 2 about here

Transfer Data

A one-way between groups analysis of variance with 4 levels (training conditions and control group) was used to analyze the transfer data. The dependent variable was performance on all 20 transfer items. A significant main effect, $F(3,87) = 10.48$ $p < .001$, was obtained. As observed in Table 2, the no-treatment control mean was significantly less (Dunnett's d' = 1.68) than any of the three practice means. No significant differences were found between the transfer means of the three training conditions.

EXPERIMENT 2

METHODS

Subjects

Ninety-eight male and female students at Iowa State University received extra credit in an undergraduate psychology class for participating as a subject. All participants were treated in accordance with APA guidelines for human subjects.

Design and Procedure

The basic design characteristics, training procedures and stimuli were identical to those used in Experiment 1, with the exception that the interval between the last practice trial and transfer task was seven days.

RESULTS

Training Data

Training data were analyzed using a 3 (type of practice) X 3 (trials) split-plot analysis of variance with repeated measures. Training means are provided in Table 3. A significant Training Condition X Trials interaction was obtained, $F(4,140) = 26.49$, $p < .001$. Differences between means were tested using Tukey's Honestly Significant Difference (HSD) test of means, HSD (.05,140) = 1.90. As indicated in Table 3, there was a significant improvement across trials within each of the three practice conditions. The one exception was the feedback practice condition where a ceiling effect was observed between trials two and three.

Transfer Data

A one-way between groups analysis of variance with 4 levels (training conditions and control group) was used to analyze the transfer data. The dependent variable was performance on all 20 transfer items. A significant main

effect was obtained, $F(3,94) = 7.58$, $p < .001$. As observed in Table 3, the no-treatment control means was significantly less (Dunnett's d' = 1.09) than any of the three practice means. No significant differences were found between the transfer means of the three practice conditions.

An additional analysis was conducted on the transfer data of the experimental groups in both Experiment 1 and Experiment 2. A 2 (experiment) X 3 (training condition) X 2 (type of transfer problem) split-plot analysis of variance was used. In this mixed design, experiment and training condition were between-subject factors, and type of transfer item was a within-subject factor. A significant within-subject factor, $F(1,138) = 80.85$, $p < .001$, was obtained. As indicated in Tables 2 and 3, all practice conditions performed significantly better on the C-E transfer items ($M = 5.99$) than the A&P-w transfer items ($M = 4.39$). No other significant differences were found.

Insert Table 3 about here

As a check on the within-subjects main effect for problem type, a dependent $t(43)$-test was used to compare performance on the C-E and A&P-w problems by the no-treatment control groups. A nonsignificant difference between performance on C-E ($M=3.59$) and A&P-w problems ($M=3.24$) was observed. This indicates that observed differences in on-line and memory-based transfer performance following C-E analogy training were due to training effects and not the result of differences in the difficulty level of the C-E and A&P-w analogy problems.

DISCUSSION

Results obtained from this study can address the initial research question proposed of whether training has a positive impact on transfer of analogy problem solving. As expected, training did have a facilitative influence on the transfer of analogy problem solving skills. Compared to the no-treatment control group, performance by all experimental groups was superior on the transfer task. These findings were evident for both immediate and delayed transfer.

Thus, we then attempted to determine if there is a significant difference between the effects of various training strategies on training and transfer performances. We describe our findings for each separately.

Training

To address the question of what had been learned during training, data reflecting encoding of the training task can be viewed in terms of the degree of learning during training. The 3 types of practice utilized in the experimental conditions were used to address this question. Practice with corrective feedback alone or combined with advice provided the basis for near ceiling performance by the 3rd trial for analogy training. When advice alone was presented prior to practice, improvement occurred but not to the same degree. Performance by the 3rd trial was only about 75% of that demonstrated by the practice groups receiving feedback or advice and feedback. These findings were evident in both Experiment 1 and Experiment 2.

Transfer

At the end of analogy training, a significant difference in the degree of learning existed between the advice group and the feedback groups. Regardless, on-line and memory-based transfer performance was at virtually the same level for all 3 practice groups. This finding seems at odds with an

accepted axiom in the transfer literature that states: "As long as structurally similar responses are required in the training and transfer tasks, positive transfer increases with degree of initial learning [Ellis, 1965]" (Gick & Holyoak, 1987, p. 23). A perspective more consistent with current information processing theory would suggest: "A theory of transfer is of necessity a theory of learning and inference" (Gick & Holyoak, 1987, p. 13). Thus, advice and practice appear to be sufficient for the development of a general schema for solving verbal analogies.

Performance by the advice practice group has implications for educational practice. Since the advice practice condition resembles the discovery method of instruction, findings suggest that an assessment of the discovery method's effectiveness should be judged in terms of promoting both positive transfer and degree of original learning. Also, the opportunity to practice must be a part of the original training or study schedule.

Studies of delayed transfer have been infrequent in contemporary work (Gick & Holyoak, 1987). Present results confirm the positive effects of schemata inducement for encoding during training and on-line transfer as well as for retrieval on delayed transfer tasks. It was believed, however, that there might be a significant difference between the transfer performance of on-line processing and
memory-based processing. This was not the case. It is apparent from comparison of the results from both studies that on-line and memory-based processing produced similar transfer effects.

Although an encoding strategy could have been used as an argument for the positive transfer effects in Experiment 1, it appears that problem solving schemata established during training was utilized for the transfer task. If only an encoding strategy was used, there would be no performance of memory-based

processing. These findings are consistent with Royer's (1979; 1986) schema interpretation of transfer. He posits that transfer involves the activation of previously learned schemata when a new problem solving situation is encountered. Similarly, Thorndyke and Hayes-Roth (1979) have provided evidence for the use of memory schema in the acquisition of transfer of knowledge. It can be concluded from past findings and the present study that transfer is schema-based under conditions of both immediate and delayed processing.

Advice may be viewed as providing the basis for the inducement of a general problem-solving strategy common to a subclass of specific problems, in this case analogy problems (Gick & Holyoak, 1983; 1987). The use of advice to induce a general schema within a problem domain is supported by the data from the advice groups. The degree of original learning on the training task was considerably less for this practice group than for the groups receiving feedback. Nonetheless, transfer performance was significantly better for the Advice group than for the no-treatment control group and no different from groups receiving feedback. This would suggest the use of a general schema to facilitate transfer within a problem domain.

Unfortunately, practice provides subjects the opportunity to draw inferences about a procedural schema. Thus, the basis for the positive transfer is confounded in the present study. Awareness of this potential confounding is important when interpreting data reflecting the use or nonuse of a problem solving schema. It may well be the case that "...problem solving can occur without learning the problem-solving schema" (Gick, 1986, p. 110). It may also be the case, however, that the task demands during acquisition were such that problem solving schemata were developed but not reflected in the dependent variable. This would be a possibility in the both Experiment 1 and Experiment 2.

Our final research question, does transfer occur across a subclass of analogy problems as well as within a subclass of analogy problems, is addressed by the analysis of transfer performance on C-E analogies and A&P-w analogies. Results revealed that all practice conditions performed significantly better on the C-E transfer items than on the A&P-w transfer items. This provides support for the argument that transfer occurs via a schema for problem-solving strategies common to a subclass of a specific problem. However, the no-treatment control group did not perform as well as the 3 experimental groups on the A&P-w analogies. This implies that training for C-E analogy problem-solving facilitates the problem solving of analogies of a different subclass (i.e. A&P-w). The problem-solving schema established during training is apparently utilized across subclasses of the specific problem. Further research addressing this issue is needed.

Further research efforts are needed to address the issues of schemata development during training and the influence of subject variables. The strength of a training for transfer paradigm is that such issues can be investigated simultaneously within the context of either an immediate transfer task (on-line transfer) or a delayed transfer task (memory-based transfer). The present paradigm can also be used to address issues such as the interaction of domain specific and strategic knowledge in academic performance. The training for transfer paradigm is an experimental approach that can be used to address research questions requiring an explanation rather than a description of the problem solving process. This conclusion is supported by a recent call from Alexander and Judy (1988) who recommend that research investigating domain-specific and strategic knowledge provide clearer operational definitions and detailed descriptions of subjects, domains, and strategies involved.

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Table 1

Training and Transfer Paradigm

Training Conditions	Practice Schedule	Transfer Task
20 C-E Analogy Problems		
Practice with Advice *	3 Practice Trials	20 New Analogies
Practice with Feedback **	3 Practice Trials	10 C-E, 10 A&P-w
Practice with Advice & Feedback	3 Practice Trials	
No Treatment Control Group		20 New Analogies 10 C-E, 10 A&P-w

* Advice preceded trial 1.

** Feedback followed each practice trial.

Note: The transfer task was the same for all groups.

Table 2

Training and Transfer Means for Experiment 1

Training Condition	Trial 1	Trial 2	Trial 3	Type of transfer problem C-E	A&P-w
Practice with Advice	10.61 (4.33)	13.27 (1.87)	14.89 (1.99)	6.11 (2.32)	4.50 (1.82)
Practice with Feedback	7.91 (3.06)	17.56 (2.63)	19.83 (.39)	5.83 (1.83)	4.48 (1.53)
Practice with Advice & Feedback	10.33 (3.64)	17.20 (3.67)	19.53 (1.22)	6.73 (1.72)	4.37 (1.90)
No-Treatment Control				3.50 (1.76)	3.20 (1.47)

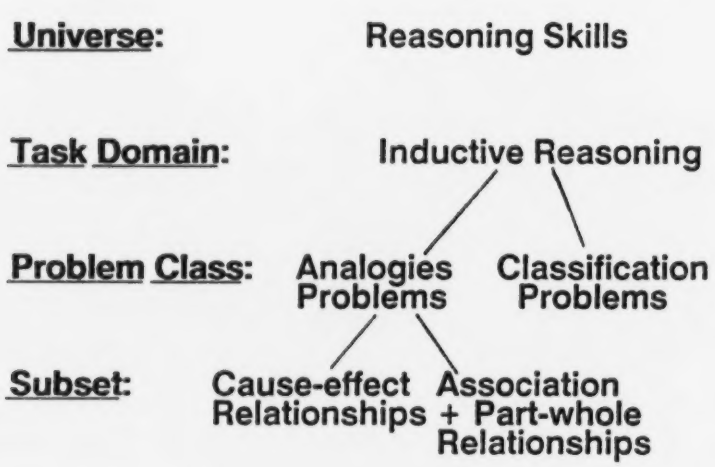
Table 3

Training and Transfer Means for Experiment 2

Training Condition	Trial 1	Trial 2	Trial 3	Type of transfer problem C-E	A&P-w
Practice with Advice	9.96 (4.04)	12.25 (2.77)	14.21 (2.81)	5.68 (1.81)	4.04 (1.75)
Practice with Feedback	8.18 (2.38)	18.27 (2.00)	19.82 (.50)	5.88 (1.88)	4.32 (2.00)
Practice with Advice & Feedback	10.39 (3.56)	17.30 (3.35)	19.61 (.84)	5.70 (1.71)	4.61 (1.47)
No-Treatment Control				3.68 (1.99)	3.25 (1.42)

Figure Caption

Figure 1. Incomplete hierarch domain structure for inductive reasoning skills.


Universe:
Reasoning Skills
Task Domain:
Inductive Reasoning
Problem Class:
Analogies Problems
Classification Problems
Subset:
Cause-effect Relationships
Association + Part-whole Relationships